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Cold Region Water Storage Practice

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■ **AN EXCAVATION in permafrost reveals a high proportion of ice to soil. White spots in the picture consist of almost pure ice. Building on this material will require unique engineering solutions. The subsoil must not be allowed to thaw under loading.**

IN ALASKA, water storage facilities must be built and operated to withstand low temperature effects. Distribution system storage needs and cold effects have resulted in a variety of solutions to the storage problem.[1]

Most Alaska water storage methods are similar to practices in other polar regions.[2, 3] But polar region storage practice differs in some aspects from storage practice in more temperate zones.[4] Icing conditions, insulation needs, structural problems, and heat requirements weigh heavily in consideration of aboveground storage facilities whether they are placed either at the ground surface or elevated.[5] Subsurface storage facilities also present construction and maintenance problems where the ground is normally permanently frozen and may be an unstable, soup-like mud when thawed.

■ **PERMANENTLY frozen ground in North Slope region shows frost polygon pattern and harsh natural erosion along drainage lines. This ground softens at the surface (a few inches deep) during the short summer and remains permanently frozen for some hundreds of feet below the thawed layer. Poor drainage makes summer the bog season.**

Early polar inhabitants solved the water storage problem simply. They cut blocks of ice in the early winter and stored the ice-harvest in a stockpile near the point where melting and usage occurred.

On more sophisticated water supply systems, such as that at Fairbanks, a small amount of below-grade storage is provided at the central water works plant and so-called "fire wells" were drilled and connected to various strategic points on the distribution system.[6] Through proper control devices and regular and standby equipment, the fire wells are brought on-stream when they are needed. Emergency fire wells have been substituted to meet the major need for distribution system storage.

Planned Seasonal Storage

Due to freezing problems in operating distribution systems and unavailability of water during much of the year, water storage facilities for several small installations are built and used on the basis of planned seasonal storage.[5, 7] Peak requirements, daily needs, as well as seasonal demands, are met by storage facilities at the point of distribution rather than by impoundment reservoirs on the source of supply.

Storage facilities in Alaska range from conventional-heated elevated tanks to special facilities to meet seasonal needs.[8] Some elevated steel tanks are insulated and heated, and in one installation, the elevated tank is enclosed in a heated, tower-like structure which serves as the carillon

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Table 1—Air Temperature Data for Selected Alaska Communities

Community	Mean Annual Temp. °F.	No. Days Max. Temp. 32° F. or Less	Approximate Annual Degree Days*
Anchorage	34.7	125	11,000
Barrow	9.9	280	20,000
Bethel	29.9	140	13,000
Cordova	40.6	60	10,000
Dillingham	34.3	...	.....
Fairbanks	26.0	160	14,000
Ft. Yukon	19.7	...	.....
Galena	25.0	180	14,000
Gambell	23.4	205	15,000
Juneau	42.1	55	8,000
Kotzebue	20.7	205	16,000
McGrath	25.4	165	15,000
Nome	25.7	185	15,000
Northway	23.0	165	16,000
Umiat	9.8	240	20,000

* For any one day, when the mean temperature is more or less than 65° F. there exists as many degree-days as there are F. degrees difference in temperature between the mean temperature for the day and 65° F.

tower for the University of Alaska. Wood stave rather than steel tanks have been used at several small installations.[9, 10] Because of foundation problems in construction facilities on permanently frozen ground (permafrost), many storage tanks (steel, wood, and occasionally concrete) have been built on the ground surface. Gravel fill mats or pads have been placed on the permafrost to serve as a base for the tank and to keep the permafrost from melting. Concrete with open ducts or hollow concrete blocks have also been used as bases for water storage tanks.

Since heat loss from a storage facility is significant as an operating expense,[5, 7] a spherical tank which exposes the least amount of surface area to the cold environment would theoretically be the best configuration for an exposed tank. But spherical water storage tanks are not in current use. Some designers have tried to reduce exposed surface area by improving the sphericity of a tank.

Temporary storage of oil or water in inflatable (so called "pillow-tank") tanks is now used commonly in some far north operations. Tanks of this type are made from fibrous materials with a rubberlike surface which seals the wall of the tank. The pillow-tank may be reusable and when empty is easily transportable. Foundation and structural requirements may be minimized by use of a temporary pillow-tank installation. Such tanks are available commercially in large and small sizes and represent an unusual departure from conventional storage practice.

A 50,000-gallon elevated tank at Fairbanks has a 5-foot diameter riser with 2 inches of insulation full height, and is equipped with a 40-foot long Horton steam heater.[10]

The 100,000-gallon elevated tank on Government Hill in Anchorage is similar to the Fairbanks tank, and also has a 5-foot diameter riser equipped with a steam heater, but is not insulated.[10] An 8 to 12-inch thickness of ice formed on the inside surface of both the riser and tank during severe cold weather. However, it was never found necessary to use the steam heater; 500 to 2,000 gpm of water were pumped to this tank from shallow galleries near Ship Creek until the Government Hill service was connected into the City of Anchorage loop, when its use was discontinued.

The original elevated tank for the Anchorage townsite was located on what is now the Public Health Service Native Hospital site, and was supplied from a pumping station near the south bank of Ship Creek below.[10] This tank was enclosed by a shingled wood frame wall and roof approximately 30 inches outside of the steel tank shell. It has been moved and is now serving a subdivision four miles south of Anchorage.

In the days of steam power (approximately 1914 to 1945), the Alaska Railroad had wayside water stations located at 35 to 50 mile intervals along the route from Seward to Fairbanks.[10] These consisted mainly of 20,000-gallon elevated redwood tubs on timber towers completely enclosed in uninsulated frame buildings. The tanks and buildings were kept warm by the steam pump and boiler housed in the same structure. The tank and riser at Nenana were enclosed and kept warm by steam piped from the adjacent pump plant.

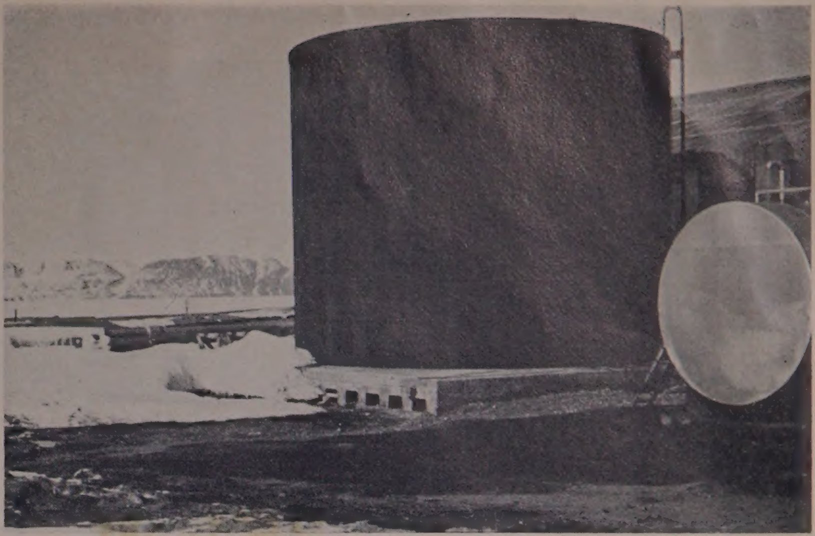
Until recently, seasonal water storage experience was restricted to practices at remote Air Force stations where winter supply requirements necessitated storage for periods as long as 8 months. These installations have modern water systems, as opposed to the more archaic procedures practiced in the villages. The tanks used for water storage have varied in size, depending on the capacity required, the number of tanks, and supplemental sources of water, if any, available during the winter. Although other stations have greater overall capacity, perhaps the largest single tank in this category is the 2-MG tank serving the Kotzebue Air Force station, 35 miles above the Arctic Circle. This tank provides over 8 months' storage capacity, and is cleaned and refilled during the short period that the water supply is available.

Tank Operation

Several plans have been used for winter operation of these tanks, each for a particular reason. The plan generally used at most Air Force stations, is to heat and maintain water in the tanks at temperatures over 50°F. Extensive heat loss results since the temperature gradient across the wall can get as high as 100°F. This practice is expensive, costing between $35 to $45 per day for heating. This operating plan has the advantage of minimizing possibilities of freeze-up in relatively short lines between buildings.

Venting presents a problem when the water is kept at 50°F or more. Evaporation from the water surface causes condensation on interior metal surfaces of the tank, raising the possibility of completely sealing the breather vent. A recently reported failure of a water storage tank in the North Slope oil fields probably was a result of pressures exerted by pumping water from the tank after the vent froze over.

A second operating plan has been suggested which would provide minimal heat to the tank, allowing formation of ice on walls and the water surface to develop additional insulation in the process of freezing. The temperature gradient across the tank wall would be lower and result in appreciable savings in heating costs. This approach has the disadvantage that an increasing portion



■ **CONCRETE base under water storage tank in far north is ventilated to permit the cold to maintain frozen earth beneath it. Thawing of permafrost under pressure can endanger stability of structure and must be considered in polar region design.**

of the storage capacity is lost as ice accumulates in the tank, necessitating a design capacity which is larger than actually needed. In trying out this operation plan, the tank failed when withdrawals caused settling of the ice. The ice was firmly attached to the interior ladder which in turn was welded to the tank wall. Failure occurred when the ladder was pulled from the tank, rupturing the wall. Future designs eliminating interior appurtenances could rectify this problem.

An operating procedure that has recently been studied,[5, 7] and recommended for all Air Force stations using temporary storage, is to maintain the tank at a temperature close to freezing, about 35 to 38°F, while providing continuous or semi-continuous circulation within the tank to prevent density stratification. Otherwise, surface icing occurs while water at the tank bottom is as high as 39°F. The study, using this procedure, has shown that, as would be expected, the lower water temperatures reduce the thermal gradient across the tank wall, resulting in smaller heat losses. The study also confirmed that exposed metal surfaces result in very significant heat losses indicating that care must be taken to insure adequate insulation over all metal surfaces, suggesting also that breather vents should be on the interior of the tank venting into the attached pump house rather than to the environment where ambient temperatures can regularly reach −40°F.

Design of a seasonal water storage tank operating as indicated above can be accomplished using computer simulation to determine the most efficient combination of insulation and heating for any particular location. This solution, in the form of a heat budget, would estimate the expected heating requirements and yearly cost of operation for any thickness of insulation. This cost when combined with the capitalized cost of construction would provide designers with the most economical size water heaters and insulation thickness. Studies are also being conducted to determine the most effective exterior surface color to minimize radiated heat loss during the long, dark, northern winters. This could also result in further reductions in the cost of seasonal water storage in the arctic.

■ **IN YEARS past, the water storage tank serving the Alaska Railroad at Nenana was enclosed and heated with steam from an adjacent pump plant to prevent freezing.**

Courtesy I. P. Cook, Alaska Railroad

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